Free Flap Coverage for Complex Primary and Revision Total Knee Arthroplasty

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Background: Free flap coverage in the setting of a total knee arthroplasty is rare. The purpose of the current study was to evaluate the outcome of patients who underwent a free flap to assist with soft-tissue coverage following a complex total knee arthroplasty.
Methods: The authors used their institutional total joint registry to retrospectively review patients undergoing a free soft-tissue flap in the setting of complex primary and revision total knee arthroplasty. Among 29,069 primary and 6433 revision total knee arthroplasties from 1994 to 2017, eight (0.02 percent) required a free flap for wound coverage. This included three primary total knee arthroplasties (0.01 percent) for posttraumatic arthritis and five revision total knee arthroplasties (0.07 percent) in the setting of infection. Median follow-up was 4 years.
Results: Free flaps included vertical rectus abdominis ($n = 3$), anterior lateral thigh ($n = 2$), latissimus ($n = 2$), and transverse rectus abdominis ($n = 1$). There were no total flap losses; however, one patient required additional skin grafting. Reoperation occurred in six patients, of which four were revisions of the total knee arthroplasty for infection ($n = 2$) and tibial component loosening ($n = 2$). One patient ultimately underwent transfemoral amputation for persistent infection. Following reconstruction, there was improvement in the median Knee Society Score (49 versus 82; $p = 0.03$) and total range of motion between preoperative and postoperative assessments (70 degrees versus 85 degrees; $p = 0.14$).
Conclusion: Free flap coverage in the setting of total knee arthroplasty was associated with a high rate of reoperation; however, the limb was able to be preserved in the majority of patients, with a reasonable functional outcome. (*Plast. Reconstr. Surg.* 148: 804e, 2021.)
CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

The number of primary total knee arthroplasties is projected to be greater than 1.5 million procedures per year in the coming decades.[1] Primary total knee arthroplasty is one of the most common procedures performed in the United States and generally results in a good patient outcome. However, increases in the volume of primary procedures, especially those performed in younger patients, will lead to a concomitant increase in revision total knee arthroplasty.[2] Complex primary total knee arthroplasty and revision procedures carry an increased risk for complications, including wound dehiscence and infection.[3] The knee is especially prone to wound healing challenges, given the thin anterior soft-tissue envelope. Care must be taken in both primary and revision procedures to optimize tissue perfusion, especially when there is concern over soft-tissue integrity.[4–7] In situations where the soft tissue is compromised, the pedicled gastrocnemius flap is often used.[8,9] When local rotational flaps fail, or when they provide inadequate coverage, treatment options become limited, and free soft-tissue flap can be a final option for limb salvage in the setting of total knee arthroplasty.

Various options to provide coverage of a total knee arthroplasty wound exist,[8–17] and currently, there is a paucity of data examining the use of free soft-tissue flaps as salvage coverage for total knee arthroplasty. The purpose of this study was to identify patients who received free soft-tissue flaps in the setting of a primary or revision total knee arthroplasty with a complex wound bed and

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report outcome of treatment with a specific focus on complications, reoperation and/or revision, and functional outcome.

PATIENTS AND METHODS

Following institutional review board approval, we conducted a single-center, retrospective analysis using our institution's total joint registry and surgical index databases. We identified all patients undergoing a free soft-tissue transfer in the setting of complex primary total knee arthroplasty or revision total knee arthroplasty from 1994 to 2017. We included patients that received a flap in anticipation of their total knee arthroplasty, at the same time as their total knee arthroplasty, and subsequent to total knee arthroplasty. During this time, 29,069 primary and 6433 revision total knee arthroplasties were performed, of which eight (0.02 percent) required a free flap for wound coverage. This included three primary total knee arthroplasties (0.01 percent) for posttraumatic arthritis and five for revision total knee arthroplasty (0.07 percent) in the setting of infection. The total knee arthroplasties were performed by an adult reconstruction subspecialty surgeon and the free flaps were performed by a plastic surgeon (Fig. 1).

Outcome Measures

Patients were followed longitudinally by our institutional arthroplasty registry to the time of implant failure, reoperation, amputation, or death. Revision total knee arthroplasty was defined as subsequent removal or exchange of any total knee arthroplasty component(s). Flap failure was defined as the need for an additional pedicled, rotational, or free flap to provide wound closure. An amputation for continued infection was not considered a failure of the flap. Reoperation was defined as any subsequent procedure on the knee during which the total knee arthroplasty component or flap was retained. Median follow-up of surviving patients was 4 ± 13 years.

Statistical Analysis

Continuous variables were compared using the Mann-Whitney *U* test. Knee Society Scores

Fig. 1. Preoperative clinical photograph (*above*, *left*) showing a wound complication following a revision total knee arthroplasty with a compromised soft-tissue envelope. The patient underwent débridement with vacuum-assisted dressings in addition to subsequent antibiotic spacer placement (*above*, *right*). This was covered using a contralateral anterolateral thigh flap (*below*).

were calculated to measure functional outcomes before surgery and at last follow-up,[18] in addition to the range of motion. Values were reported as medians ± interquartile range. Statistical analysis was performed using JMP Pro 14 (SAS Institute, Inc., Cary, N.C.) with statistical significance set at a value of $p < 0.05$.

RESULTS

Flap Reconstruction Group

The flap reconstruction group of patients consisted of four women and four men with a median age and body mass index of 54 ± 20 years and 29.8 ± 12.6 kg/m^2, respectively. Before the need for a free flap, patients underwent a mean of 6 ± 3 operations on the knee with a median wound size of 33 ± 119.7 cm^2 (Table 1). All patients had a history of previous surgery about the knee that compromised the soft-tissue envelope.

Five patients had a planned free flap performed before their arthroplasty procedure with a median time from free flap to arthroplasty of 105 ± 61 days. In these patients, all were evaluated by a multidisciplinary team consisting of plastic and reconstructive surgeons in addition to adult arthroplasty surgeons to evaluate the soft-tissue envelope before surgery. The decision to perform a free flap before surgery was made because of previous incisions over the knee from an open reduction and internal fixation in the setting of a posttraumatic deformity ($n = 3$) or at the time of explantation of an infected total knee arthroplasty before reimplantation ($n = 2$). One patient underwent simultaneous arthroplasty and flap coverage secondary to the wound being unable to be closed with a local flap. Two patients had free flaps performed postoperatively because of wound complications at 2 weeks and 9 months, respectively, following a complex revision total knee arthroplasty.

Free flaps included vertical rectus abdominis myocutaneous flaps ($n = 3$), anterior lateral thigh flaps ($n = 2$) (Fig. 1), latissimus flaps ($n = 2$), and a transverse rectus abdominis musculocutaneous flap ($n = 1$) (Fig. 2). All anastomoses were performed using a microscope and performed in either an end-to-side ($n = 6$) or end-to-end ($n = 2$) fashion. The recipient vessels included anterior tibial ($n = 3$), superficial femoral ($n = 2$) posterior tibial ($n = 1$), or sural ($n = 1$) vessels. In one patient, an anastomosis was attempted at the superficial femoral vessels; however, because of severe atherosclerotic disease, a polytetrafluoroethylene (W. L. Gore and Associates, Flagstaff, Ariz.) graft was needed to bypass the superficial vessel from the common femoral artery in the groin to the popliteal artery. The pedicle of the flap was then sutured to the polytetrafluoroethylene graft. It should be noted that in the two additional cases where the superficial femoral vessels were used, an attempt was previously made at using a genicular artery; however, the arterial anastomosis did not provide adequate flow. The venous anastomosis was performed using a coupler ($n = 5$) or suture ($n = 3$). All operations except for the cases of the latissimus flaps were performed with the patient in the supine position, which allowed the operative leg to be frog-legged for access to the medial thigh to allow access to the femoral vessels. The anterior tibial vessels were found by extending the distal portion of

Table 1. Patients Undergoing Free Flap Coverage and Complex Total Knee Arthroplasty

Patient	Indication	Wound Location	Wound Size (cm^2)	Prior Operations	Free Soft-Tissue Flap	Outcome at Last Clinical Follow-Up	Follow-Up (yr)
1	Traumatic	Anterior	Previous incisions	2	Latissimus	Retained TKA and flap	26
2	Infection	Anterior	35	8	Vertical rectus abdominis	Retained TKA and flap	1 (died of unrelated causes)
3	Intraoperative wound	Anterior	14	3	Vertical rectus abdominis	Retained TKA and flap	3
4	Traumatic	Anterior	Previous incisions	8	Transverse rectus abdominis	Retained TKA and flap	12
5	Traumatic	Anterior	17.5	6	Latissimus	Revision TKA flap, retained	27
6	Infection	Anterior	176	9	Vertical rectus abdominis	Revision TKA, amputation	3 (time of amputation)
7	Infection	Anterior	252	3	Anterior lateral thigh	Revision TKA, flap retained	4
8	Infection	Medial	31.5	7	Anterior lateral thigh	Revision TKA, flap retained	4

TKA, total knee arthroplasty.

Fig. 2. Preoperative clinical photograph (*above*, *left*) showing the compromised posttraumatic soft-tissue envelope. The patient was taken to surgery for a planned staged total knee arthroplasty and free flap. The compromised soft tissue was débrided (*above*, *right*) and a transverse rectus abdominis musculocutaneous flap was harvested. The patient required a flap advancement; however, after this, the flap was healing and the patient was placed in an immobilizer (*below*, *left*). The patient underwent total knee arthroplasty 2 months after the flap coverage and, following surgery, had full extension and flexion to nearly 90 degrees (*below*, *right*).

the knee incision. All flaps were harvested with a skin paddle; however, three patients (38 percent) required an additional split-thickness skin graft. Drains were placed under the flap with the goal to remove the drains in the first 24 to 48 hours with the patients on intravenous antibiotics if there was an underlying total knee arthroplasty, as extended drain placement is a potential source of recurrent infection. Patients were kept on bed rest for 5 days with the leg elevated in extension with a splint with a cutout anteriorly to allow for visualization of the flap. The intraoperative splint was then changed

to a custom-fabricated posterior slab splint, again with a cutout to not place pressure on the flap. Following the bedrest, a formal dangling protocol was not consistently used; the patients were limited to standing for less than 40 minutes per hour with their leg elevated the remaining times.

Outcome of Free Flaps in Complex Total Knee Arthroplasty

After the procedure, four patients underwent revision surgery at 5, 15, 37, and 292 months postoperatively. Three of these cases were repeated revision total knee arthroplasties (revision at 5, 15, and 37 months), whereas one was a first-time revision of a complex primary total knee arthroplasty (292 months). Indications for revision included recurrent infection ($n = 2$) and aseptic tibial component loosening ($n = 2$). One of these patients subsequently underwent transfemoral amputation because of intractable infection.

There were no total flap losses; however, one patient required an additional split-thickness skin graft because of necrosis of the skin paddle. All flaps healed and were retained at final follow-up. Additional nonrevision reoperations including irrigation and débridement of a superficial wound necrosis ($n = 2$) and advancement of flap for necrosis of the tip of the flap skin paddle ($n = 1$). Both patients who had a failed anastomosis into a genicular vessel had a wound complication.

At most recent follow-up, there was a significant improvement in the Knee Society Score from a median of 49 ± 21 preoperatively to 82 ± 30 postoperatively ($p = 0.03$). In addition, there was an improvement in the patients' median range of motion from preoperatively to postoperatively; however, this failed to reach statistical significance (70 ± 78 degrees versus 85 ± 18 degrees; $p = 0.14$).

DISCUSSION

Wound complications following total knee arthroplasty can be a devastating complication and lead to potentially limb-threatening outcomes. Historically, the use of a local rotational gastrocnemius flap has been the workhorse in these situations. However, when these are inadequate, free flap coverage is needed. The results of this series shows that free flaps allow limb salvage, improved functional scores, and improved range of motion.

A healthy wound bed is critical for healing. Prior surgical incisions disrupt perfusion to the surrounding local tissues and disrupt the natural anastomotic blood flow to the skin.[19] Reconstruction allowing soft-tissue expansion or coverage of a wound bed has been shown to decrease complications in the setting of prior incisions when done with either prophylactic or concurrent rotational flaps.[20,21] As is the case with most of the current literature, the majority of our patients had their flap coverage performed in a staged fashion, with five of the patients receiving their free flap coverage before their definitive knee reconstruction. This is similar to the use of free flaps for wound coverage to enhance the local soft tissue during a Masquelet technique for providing a well-vascularized wound bed before reconstruction.[22–24] Although only free flaps were used in the current series, other options to provide wound coverage about the knee that may negate a free-tissue transfer exist (i.e., perforator flaps).[10–16] The current series focused on those patients that were not suitable candidates for local flap coverage, such as gastrocnemius, reverse anterolateral thigh, or propeller perforator flaps. The reason for exclusion of these options includes wounds size, proximal wound extent, disruption of local flap pedicle(s), proximity of the wound, and preexisting peripheral vascular disease. These factors can make the use of perforator-based flaps unreliable.[10–16]

Although previous series have suggested using the geniculate vessel as the primary recipient vessel for lower extremity reconstruction,[25] in the current series, these did not provide adequate inflow. As such, the femoral artery was exposed through the adductor canal, allowing for an end-to-side anastomosis or use of the tibial vessels after confirming the patient has adequate runoff to the foot. Our current practice is to obtain a computed tomographic angiogram for all patients preoperatively, which provides adequate visualization of perforators and side branches greater than 1.5 mm in diameter.[26] This allows us to evaluate the geniculate system and spare the geniculate and saphenous branch if possible to preserve what blood supply remains to the surrounding knee, which is based on the genicular vessels,[27] as it is important to note that both patients who had a failed anastomosis into the genicular vessels had a wound complication. The anterior tibial vessels are optimally located for microvascular anastomosis in their anterior position and therefore prevent using a significant portion of the flap just to reach the defect. The challenge is their deep location and numerous concomitant venous connections typical in this region.

Free muscle flaps bring muscle tissue to the wound defect, providing both bulk and robust blood supply. Because the size of the tissue that

can be transferred to the area of need is dictated by the soft-tissue deficit, preoperative planning of the location of transfer can ensure adequate coverage. The added blood supply and bulk both have been shown to improve the ability to eradicate infection and improve wound healing because of the increased ability of antibiotic delivery.[28–31] Although there may be an advantage in terms of knee range of motion when using a fasciocutaneous flap such as an anterolateral thigh flap, this was not able to be assessed in this study. Because of the limited number of patients in the current series, it is difficult to make a comparison between knee range of motion in patients who undergo reconstruction with a fasciocutaneous flap and those who undergo reconstruction with a muscle flap. It should be noted that there was an improvement in range of motion in all patients. Although it was a modest improvement, functionally for the patient, it can have a substantial impact on quality of life, as it takes 90 degrees of knee flexion to sit comfortably and rise from a chair.[32]

Historically, a pedicled gastrocnemius flap is often sufficient to provide coverage for a wound complication in the setting of a total knee arthroplasty.[8] However, in cases of prior surgery and prolonged immobility, the pedicle to the gastrocnemius flap can be injured or atrophic, making this flap unsuitable for coverage. In addition, these flaps are often used in the setting of infection, where the placement of an antibiotic spacer can lead to surrounding fibrosis, making mobilization of this flap difficult. Larger wound size has also been shown to increase the risk of amputation following a pedicled gastrocnemius flap.[8] In the current series, the patient either had a history of multiple surgical procedures or a large soft-tissue defect. Although consideration for the use of both the medial and the lateral gastrocnemius can be performed, in these high-risk wounds, when considering using both gastrocnemius flaps, a free flap should be considered.

This study must be interpreted in light of important limitations. First, we report on a rare and complex clinical scenario. As such, the primary limitation is the small sample size and marked heterogeneity of the cohort. This precludes drawing any firm conclusions tied to statistical inference. In addition, we recognize the biases in surgical technique and decision-making that are implicit in single-center studies, in addition to the use of only free flaps in the current series. However, in these complex patients where wounds demand a large soft-tissue envelope, there are few options available.

Overall, this series shows that free flaps have the potential to provide coverage and improve functional outcomes; however, reoperation rates remain high. In cases where free flap coverage is needed to salvage a total knee arthroplasty, patients should expect a high rate of complications and eventual need for additional surgery; however, the limb is able to be preserved in a majority of patients, with a reasonable functional outcome and modest improvements in range of motion.

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